THE LIGHTNING SPARK BARRIER

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AD P002240

ABSTRACT

Lightning protection of modern aerospace vehicles must prohibit sparking in critical fuel vapor areas. In the past, it has been particularly difficult to keep mechanical fasteners from sparking during a lightning event. Attempts to seal off the fasteners from the critical fuel vapor area by manual application of sealant material have proven to be ineffective due to gaps and voids produced by the application process. A technique was developed by Douglas Aircraft Company to control the application of dielectric sealant material to isolate the mechanical fastener sparking from the critical fuel vapor area. The technique consists of a specially designed dielectric cap that fits over the fastener, providing uniform and controlled application of dielectric filler material. An adequate thickness of filler material provides a barrier that prevents the sparks from entering the critical fuel vapor area. The Lightning Spark Barrier is applicable to a wide variety of installations, including those with composite materials. A patent has been applied for.

THE MECHANICAL FASTENERS are used extensively in modern aerospace vehicles to secure doors, access covers, and other hardware. A typical fastener in a cross section view is shown in Figure 1.

The mechanical fasteners are installed primarily to carry structural loads. The fasteners are usually chosen from a vendor's pre-existing inventory; the shape and design are not directly related to preventing sparking. Sparking of mechanical fasteners in a critical fuel vapor area of an aircraft must be prevented during a lightning event. A critical fuel vapor area is defined as an area where fuel vapor and air exist in a stoichiometric mixture that can be ignited by a low-intensity spark. (1)*

Typically, hardware is attached by a bolt through a hole into the mechanical fastener. The hardware is usually electrically grounded to the aircraft fuselage through the attachment bolts into the mechanical fastener. Dielectric paint and gaskets typically prevent the hardware from making electrical contact to the fuselage other than at the fasteners. Therefore, during a lightning event, when the lightning discharge channel contacts the external hardware, the discharge current must flow through the bolts and then through the mechanical fasteners. Sparking occurs when there is a contact resistance at the interface between two adjacent conductors in the current flow path. The current flow path in a typical fastener during a lightning discharge is shown in Figure 2.

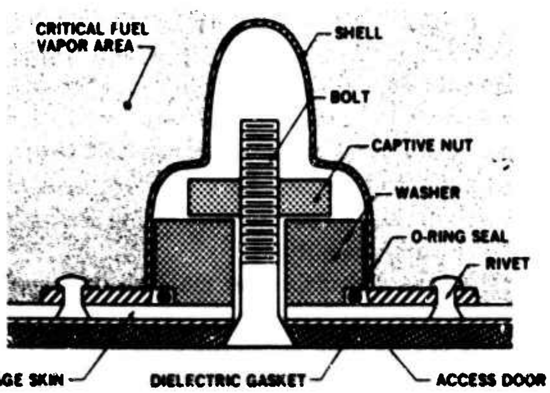

FIGURE 1. CROSS SECTION OF TYPICAL FASTENER

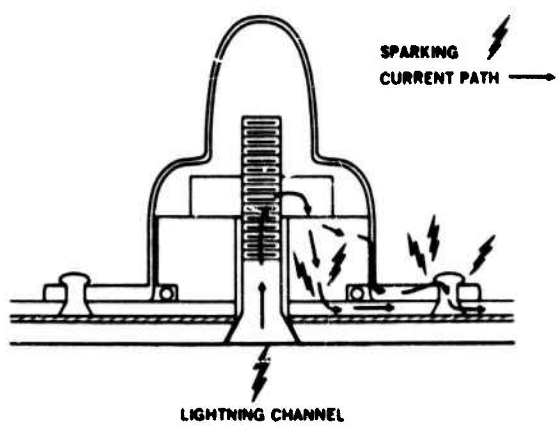

FIGURE 2. CURRENT PATH AND SPARKING IN TYPICAL FASTENER DURING LIGHTNING DISCHARGE

*Numbers in parentheses designate references at end of paper.

Typical fastener installations were subjected to lightning simulation testing to determine the portions of the fasteners that spark. Microscopic examination of the fasteners revealed that the areas of sparking were numerous, even with proper electrical bonding at interfaces. The areas of sparking on the fastener were dependent upon the exact physical construction of the mechanical fastener, and its interface with the fuselage.

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Many investigators have examined the problem of sparking of mechanical fasteners in critical fuel vapor areas (2, 3, and 4). Several researchers have attempted to use sealant material around the fastener to prevent the sparks from entering the critical fuel vapor area, but abandoned this method when it failed in lightning simulation testing. The reason for failure in all cases was small gaps, voids, and variations in thickness from the manual application of the sealant material. Douglas lightning simulation testing with manual application of sealant material around the fasteners duplicated the results of previous investigators (Figure 3).

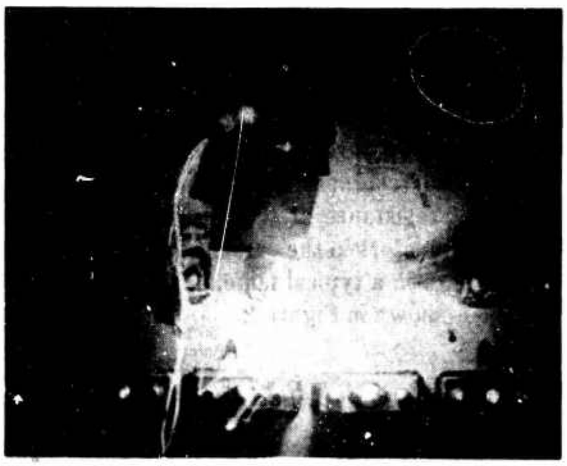

FIGURE 3. PHOTOGRAPHIC EVIDENCE OF MECHANICAL FASTENER SPARKING DURING LIGHTNING SIMULATION TESTING

Douglas has recently developed an effective solution to overcome the difficulties previously encountered in using dielectric sealant material. A technique was developed to apply dielectric sealant in a controlled manner to prevent the voids, gaps, and variations in thickness found in other techniques. This technique is the Lightning Spark Barrier.

The technique consists of a specially designed dielectric cap that is placed over the mechanical fastener in the critical fuel vapor area. It controls the thickness of the applied dielectric sealant and eliminates voids and gaps (Figures 4, 5, and 6). The cap can use exter-

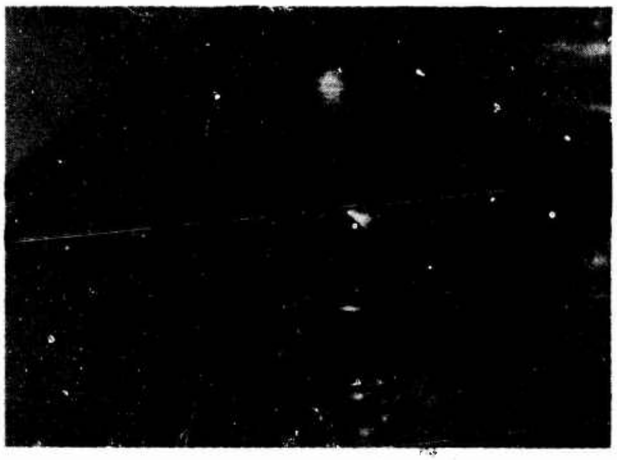

FIGURE 4. FASTENER WITH CUTAWAY SHOWING INTERIOR OF LIGHTNING SPARK BARRIER

FIGURE 5. FASTENER WITH CUTAWAY SHOWING INTERIOR OF LIGHTNING SPARK BARRIER

nal portions of the fastener, such as the crimp shoulder, to align the cap over the fastener. Although proper alignment is not necessary in the design of the cap, a cap designed to align itself properly over the fastener saves weight and space.

The dielectric filler material inside the cap can be applied in two ways: (1) The cap is first placed over the fastener and the dielectric filler is injected through small holes in the cap, or (2) the filler material is first placed in the cap and then the cap and sealant are placed over the fastener. Both methods have proven to be satisfactory. The choice of either is dependent upon installation conditions.

After the dielectric filler material has cured and hardened over the fastener, it acts as a barrier and prevents sparks from physically entering the fuel vapor area. The dielectric barrier material must be of sufficient thickness around the sparking areas of the fastener to provide an adequate barrier against the

FIGURE 6. FASTENER AND LIGHTNING SPARK BARRIER ON ACRYLIC SHEET SHOW DIELECTRIC FILLER MATERIAL IS FREE OF VOIDS AND GAPS

sparks and the joule heating pressure of the sparking. This thickness dimension will depend on both the shape of the fastener and the dielectric filler material chosen. Lightning simulation testing in accordance with known spark detection techniques (5) is always necessary to verify the design of the lightning spark barrier for each type of fastener. Theoretical predictions with formulas are not practical because of the complex geometries involved. The dielectric filler material does not have to be a sealant. A patent application for the Lightning Spark Barrier was filed in December of 1981.

ADVANTAGES OF THE LIGHTNING SPARK BARRIER

Previously, large, heavy mechanical fasteners were used in critical fuel vapor areas to carry the lightning discharge current without sparking. With the addition of the Lightning Spark Barrier, smaller mechanical fasteners can be chosen based on structural criteria alone. The Lightning Spark Barrier adds little weight to an aircraft, and actually saves weight over present designs.

The Lightning Spark Barrier works with either anodized or alodine coated fasteners. This gives the structural designer more latitude in corrosion prevention in the applications using mechanical fasteners.

The Lightning Spark Barrier can be installed any time during the life of an aircraft. An aircraft can be retrofitted with the Lightning Spark Barrier if a critical fuel vapor is defined after the airframe is in production. The straightforward design of the Lightning Spark Barrier requires minimal skills for installation, making it easy for airline service personnel to retrofit the aircraft.

The dielectric filler material of the Lightning Spark Barrier can also serve as a pressure seal. In many cases, sealant material would be applied around the fastener for pressure containment reasons alone. The Lightning Spark Barrier can be used as a pressure seal also.

The dielectric cap for the filler material not only provides some protection against sparking, but, when left in place after the filler has cured and hardened, the cap provides protection against mechanical damage to the barrier material by maintenance crewmen. In access doors, it is especially important to prevent service personnel from accidentally gouging the dielectric filler material of the spark barrier.

One of the most promising applications of the Lightning Spark Barrier is in semiconductive composites. Due to the semiconductive nature of the composite, the interface between the mechanical fastener and the composite will have a high contact resistance, giving rise to sparking during a lightning event. The Lightning Spark Barrier is potentially the only solution available to prevent mechanical fasteners from sparking in a critical fuel vapor area where semiconductive composites are involved.

CONCLUSION

Sparks from a mechanical fastener cannot be allowed to enter a critical fuel vapor area during a lightning event. The Lightning Spark Barrier employs a dielectric cap that controls the application of a dielectric barrier material that prevents sparks from entering the critical fuel vapor area. The Lightning Spark Barrier has many advantages over other techniques, especially in composite installations.

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